BIOLOGY OF SILVER SCABBARD FISH, *LEPIDOPUS CAUDATUS* (TRICHIURIDAE), FROM THE IONIAN SEA (EASTERN-CENTRAL MEDITERRANEAN)

by

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ABSTRACT. - *Lepidopus caudatus* was collected during trawling and long-line surveys carried out in 1996 and 1997 in the Ionian Sea (Eastern-Central Mediterranean). The smallest specimen measured 13.3 cm in total length, the greatest was 163.5 and 150 cm in females and males respectively. The population was almost exclusively sampled within the first 400 m with juveniles mostly distributed on the continental shelf. At depths greater than 400 m both small and large specimens were collected. Commercial trawls collected mostly small and immature specimens. Experimental trawls, with a higher vertical opening, caught a significantly higher proportion of adult specimens, although juveniles represented the most abundant fraction of the stock. The longline only sampled large individuals. The maximum age was 7+ in females and 5 in males. No significant differences were shown between the length-weight relationship of the two sexes. The von Bertalanffy growth parameters were: $L_\infty = 182.46 \pm 3.9$ cm, $k = 0.30 \pm 0.014$, $t_0 = -0.50 \pm 0.032$ in females and $L_\infty = 174.27 \pm 3.7$ cm, $k = 0.31 \pm 0.013$, $t_0 = -0.53 \pm 0.023$ in males. The smallest mature specimen measured 92 cm total length in females and 90 cm in males. Mature specimens of both sexes and young-of-the-year individuals were found both in spring and autumn.

RÉSUMÉ. - Biologie du sabre argenté, *Lepidopus caudatus* (Trichiuridae), dans la mer Ionienne (Méditerranée orientale et centrale).

Lepidopus caudatus a été capturé pendant des campagnes de chalutage et de pêche à la palangre effectuées en 1996 et 1997 en mer Ionienne (Méditerranée orientale et centrale). Le plus petit exemplaire capturé mesurait 13,3 cm (TL), les plus longs, 163,5 cm (femelle) et 150 cm (mâle). La population a été échantillonnée dans les 400 premiers mètres de profondeur, les juvéniles étant répartis surtout sur le plateau continental. Au-delà de 400 m, des individus jeunes ou adultes ont été capturés. La pêche commerciale capture surtout des individus jeunes et non matures. Une proportion plus grande d'adultes a été capturée avec un chalut à haute ouverture verticale, même si les juvéniles représentaient encore la fraction la plus abondante du stock. La palangre de fond a toujours capturé des individus adultes. L'âge le plus élevé a été 7+ ans parmi les femelles et 5 ans parmi les mâles. Aucune différence significative n'a été notée entre les relations longueur-poids des deux sexes. Les paramètres de croissance de von Bertalanffy étaient: $L_\infty = 182{,}46 \pm 3{,}9$ cm, $k = 0{,}30 \pm 0.014$, $t_0 = -0{,}50 \pm 0{,}032$ pour les femelles et $L_\infty = 174{,}27 \pm 3{,}7$ cm, $k = 0{,}31 \pm 0{,}013$, $t_0 = -0{,}53 \pm 0{,}023$ pour les mâles. Les plus petits exemplaires matures mesuraient 92 cm (LT) parmi les femelles et 90 cm parmi les mâles. Les exemplaires matures des deux sexes et les juvéniles 0+ ont tous été pêchés en automne et au printemps.

Key words. - Trichiuridae - *Lepidopus caudatus* - MED - Ionian Sea - Distribution - Population structure - Biology.

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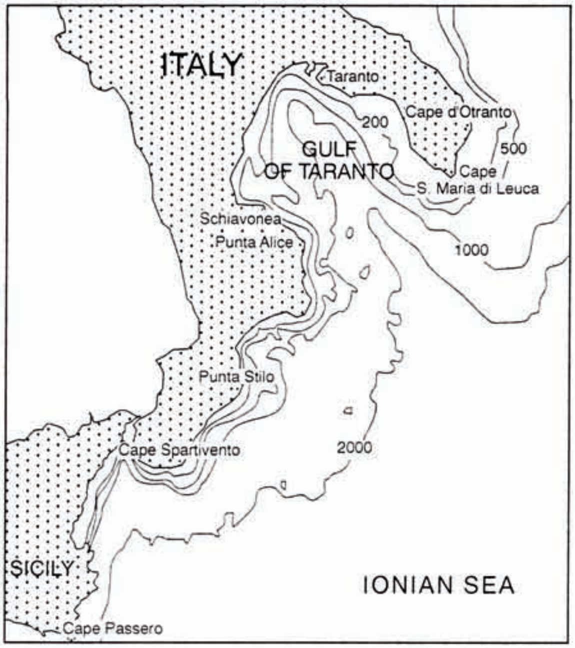

Fig. 1. - Map of the study area in the Ionian Sea (eastern-central Mediterranean).

The silver scabbard fish, *Lepidopus caudatus* (Euphrasen, 1788), is a teleost distributed in the temperate waters of all oceans and throughout the Mediterranean Sea. It has benthopelagic habits throughout the continental shelf and slope (Nakamura and Parin, 1993).

The knowledge on the biology of this fish in the Mediterranean Sea comes mainly from studies carried out in the north-western basin (e.g., Macpherson, 1979; Orsi Relini *et al.*, 1989; Moli *et al.*, 1990; Palandri and Orsi Relini, 1992; Demestre *et al.*, 1993). In the eastern-central Mediterranean Sea, despite several investigations on eggs and larvae distribution being conducted over many years (Raffaele, 1888; Lo Bianco, 1909; Padoa, 1956; Spartà, 1959; Karlovac and Karlovac, 1976), the scientific information on *L. caudatus* is generally limited to its presence and distribution in the various basins (e.g., Pastore, 1976; Parenzan, 1983; Papaconstantinou 1986; Bello and Rizzi, 1988; Matarrese *et al.*, 1996).

Particularly, concerning the Ionian Sea along the south-eastern Italian coast, although the silver scabbard fish ranks among the most abundant fish species collected during experimental trawling (Matarrese *et al.*, 1996), no data on its biology have been published until now. In this area, only the large specimens have commercial value while the small ones are generally discarded. The former can be selectively caught by longline while the latter are mostly fished during trawling, as observed in the western Mediterranean (e.g., Palandri and Orsi Relini, 1992; Demestre *et al.*, 1993).

During recent years data on the silver scabbard fish from the Ionian Sea have been collected as part of study projects on the demersal resources using mainly trawl gears and to a lesser extent the longline. The aim of this paper is to provide the first contribution to the knowledge of its distribution, size structure and biology from this eastern-central Mediterranean basin.

MATERIALS AND METHODS

The data were collected during trawling and long-line surveys carried out in 1996 and 1997 in the Ionian Sea, between Cape Otranto and Cape Passero (Fig. 1).

An experimental trawl net was used during June 1996 and June 1997 in the context of an international bottom trawl survey funded by EC-DGXIV (MEDITS project). The experimental trawl net was a nylon otter trawl GOC73 type (Bertrand, 1994), with stretched mesh of 20 mm in the codend. The horizontal and vertical net opening, measured by means of the SCANMAR sonar system and depending on various factors (depth, warp length, towing speed, etc.), were approximately 17 m and between 2.0 and 3.0 m respectively (Fiorentini, 1994).

A commercial trawl net was used during November-December 1996 and September-October 1997 as part of the study on demersal resources financed by Italian government. The commercial net was an Italian type nylon otter trawl net, with stretched mesh of 40 mm in the codend. The horizontal and vertical net opening, ranged respectively from 21.71 to 25.09 m and from 0.80 to 0.73 m (Fiorentini *et al.*, 1994).

An experimental longline was used during June-July 1996 and May-June 1997 as part of a study project on the hake spawners unavailable to trawling funded by the E.C. The experimental longline was a bottom type approximately 4000-5000 m long, with 450-750 hooks at distances of 6-9 m. The baits used consisted of herrings, *Sardina pilchardus* and *Sardinella aurita*. Each longline survey lasted 4 days in the northern area of the investigated basin. Fishing duration of the longline was around 4-8 hours each day.

A professional motor-powered vessel was hired for each project. The depth range investigated was between 10 and 800 m during trawl and between 200 and 800 m during longline surveys.

The sampling design adopted during trawl surveys was random-stratified. The number of hauls was proportional to the surface area of each depth stratum. These were: 10-50 m; 50-100 m; 100-200 m; 200-500 m; 500-800 m. Sampling stations during longline surveys were allocated on transects according to depth.

Total length (cm, TL), weight (g) and sex were recorded for each specimen. Length-frequency distributions were performed for the whole population sampled during each study period, grouping lengths into 1 cm intervals. The depth distribution pattern was analysed for the trawl survey data of both 1996 and 1997, due to the high number of individuals sampled. Sex ratio by depth was computed after pooling the trawl surveys of spring and autumn of the two years. Sex ratio by size was calculated for all the pooled trawl data. Statistical differences between the number of females and males by survey and depth were determined using the G-test (Sokal and Rohlf, 1969).

The length-weight relationship was computed for the two seasons according to the power curve function transformed into a straight line equation using natural logarithms: $\ln \text{Weight} = \ln a + b \ln \text{TL}$. The linear regression equations for the two sexes were compared statistically using the Chow-test (Koutsoyiannis, 1977). This test verifies whether there is a significant difference between both the slope (b) and the intersect (a) of two regression lines estimated from two different samples.

Both sagittae were removed from 450 specimens whose sizes were between 18.6 to 163.5 cm TL. The smallest sagittae were read as whole, while the sagittae belonging to the specimens greater than 110 cm total length were ground with sandpaper to obtain the best reading. Otoliths were placed in a black dish with glycerin (30%) and alcohol (70%) to improve reading. The opaque and translucent zone deposition pattern was con-

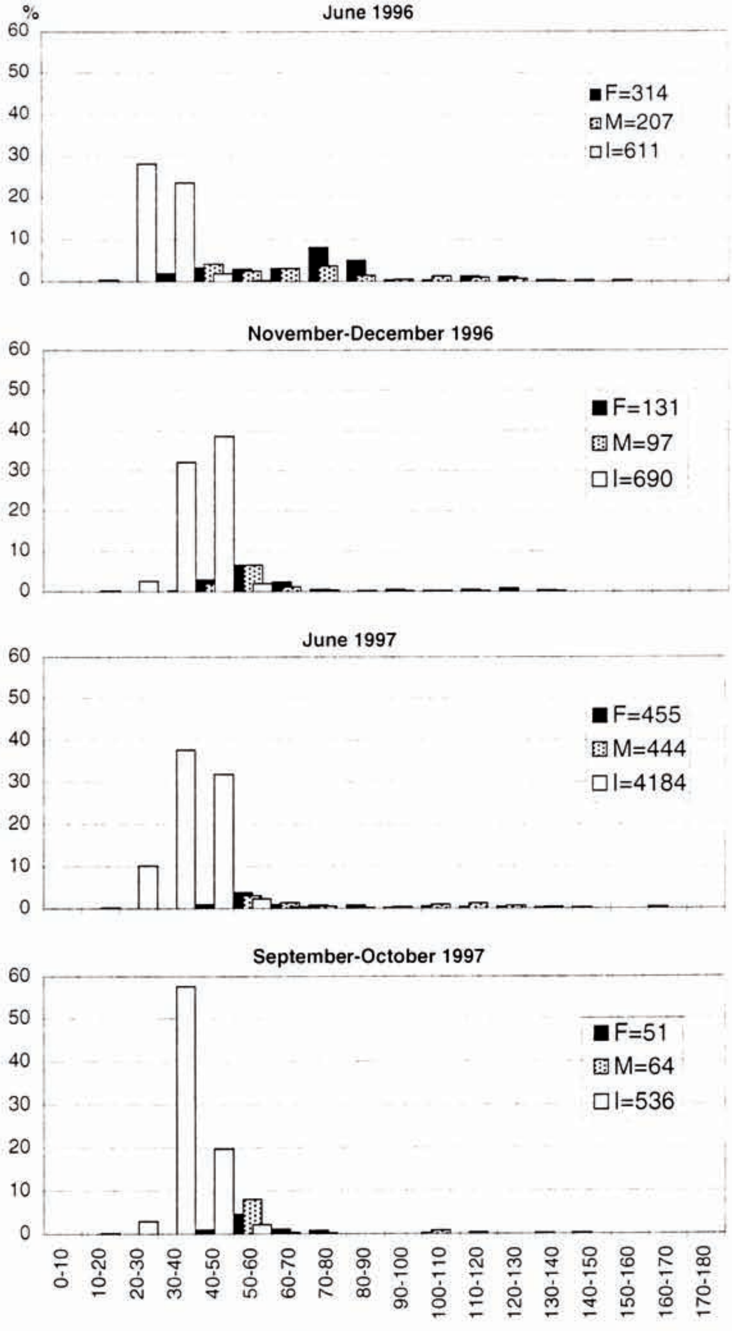

Fig. 2. - Length-frequency distribution of *Lepidopus caudatus* (F: females; M: males; I: undetermined individuals) caught by experimental trawl (June 1996 and 1997) and commercial trawl (November-December 1996 and September-October 1997) in the Ionian Sea.

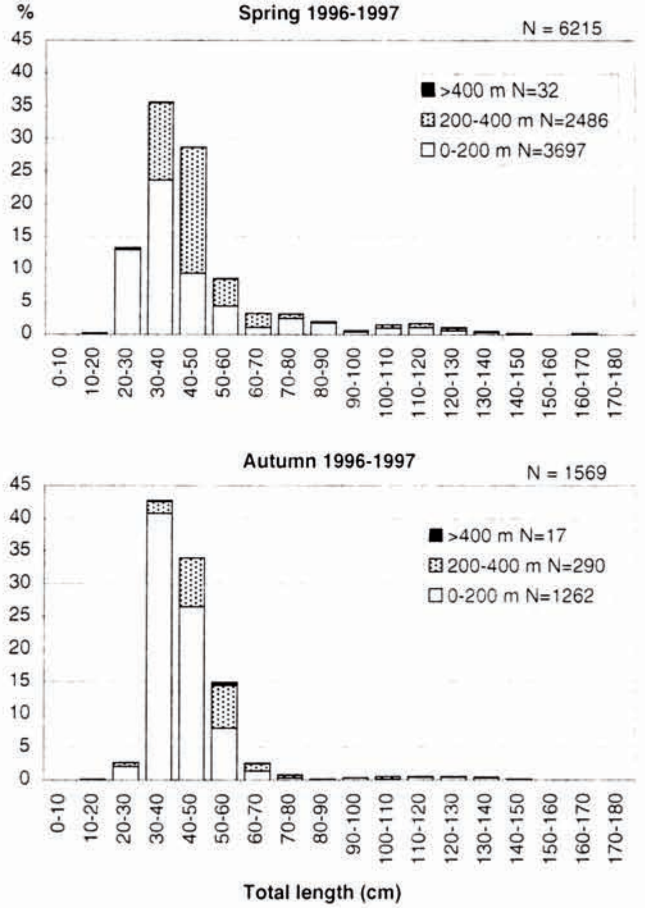

Fig. 3. - Length-frequency distribution by depth of *Lepidopus caudatus* caught by experimental trawl (Spring 1996-1997) and commercial trawl (Autumn 1996-1997) in the Ionian Sea.

sidered as an annual event (Moli *et al.*, 1990). Otoliths were read at least twice independently by two observers under a stereoscope using reflected light. If agreement was not reached, the otoliths in question were excluded from the growth estimate. Only 382 sagittae were used to obtain the age-length key for each sex (187 for females and 195 for males).

The von Bertalanffy (1938) function was adopted to model the growth pattern. The least square method was applied to the age-length relationship implemented in the LFSA program (Sparre, 1987). The program uses a non-linear least squares procedure which estimates the growth parameters in such a way that the sum of the squares of the deviations between the model and the observations is minimized. Since the von Bertalanffy growth parameters L_∞ and k are inversely correlated, the growth performance index (ϕ') (Munro and Pauly, 1983) was computed in order to compare growth rates in the two sexes.

Since mature fish are assumed to grow less than the juveniles in relation to the fact that more energy is directed to reproduction than growth (Wotton, 1998), the maturity

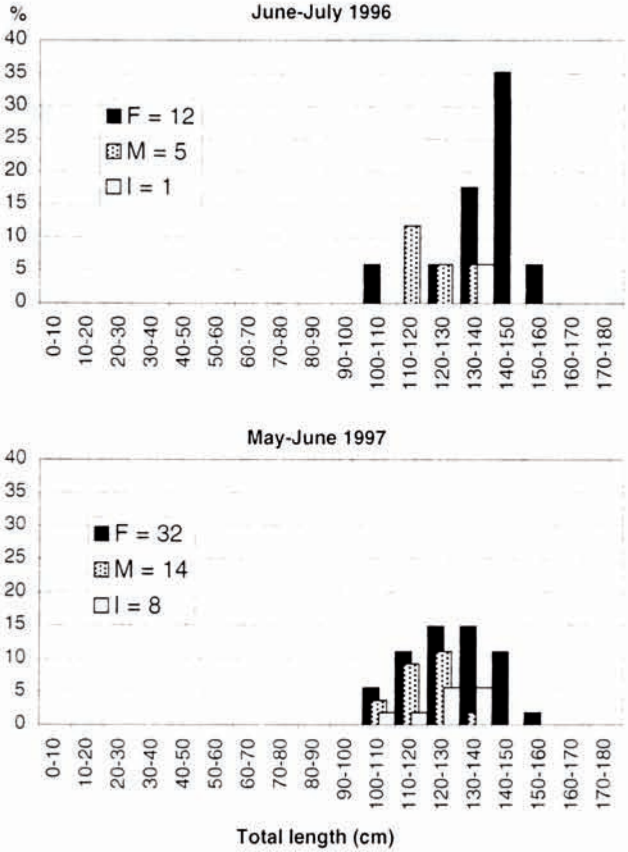

Fig. 4. - Length-frequency distribution of *Lepidopus caudatus* (F: females; M: males; I: undetermined individuals) caught by experimental longline in the Ionian Sea.

stage of the gonads by survey and size was studied in both sexes. Maturity was recorded macroscopically according to Nikolsky (1963), considering the following stages: II) resting (immature); III) maturing; IV) mature; V) running ripe; VI) spent. The sex of the virgin gonad (stage I) was indistinguishable in the very small specimens. The size-frequency distribution by maturity stage was performed for all the sexed specimens collected by both trawl gears and longline.

RESULTS

Structure of the sampled population

Although a wide range of sizes was shown in the sampled population by trawling, most of the specimens were smaller than 60 cm TL. These specimens made up the first modal component in each survey and were mostly indeterminate (unsexed) due to their virgin gonads (Fig. 2). The smallest specimen measured 13.3 cm in total length, the greatest was 163.5 and 150 cm in females and males respectively. Size composition by

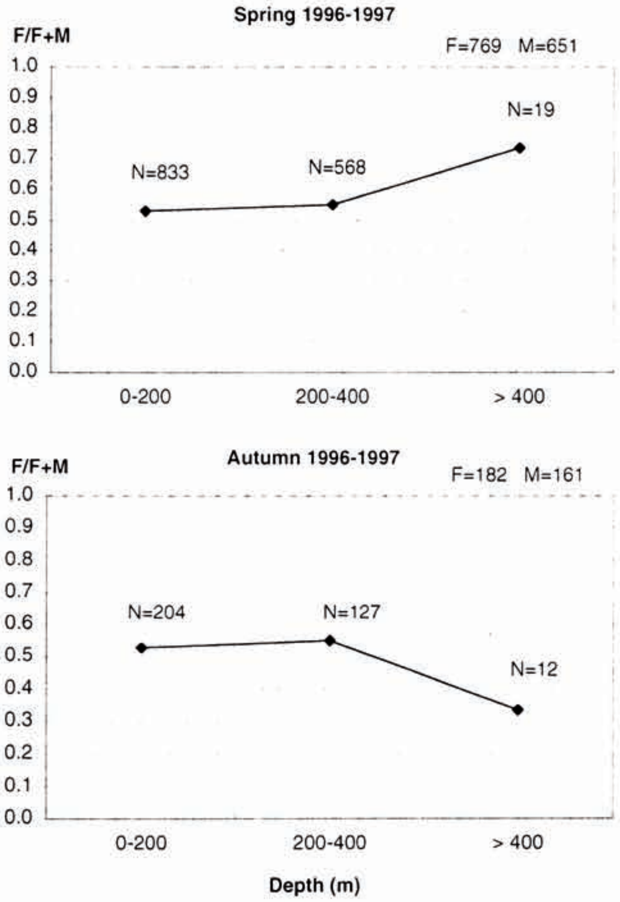

Fig. 5. - Sex ratio by depth of *Lepidopus caudatus* caught by experimental trawl (Spring 1996-1997) and commercial trawl (Autumn 1996-1997) in the Ionian Sea.

depth for data pooled by season showed that the population was almost exclusively sampled within the first 400 m with the juveniles mostly distributed on the continental shelf (Fig. 3). At depths greater than 400 m both small and large specimens were collected. Linear regression analysis between depth and total length gave a significant result ($p < 0.01$) for the raw pooled data of spring trawl surveys, although with small r (0.28) and r^2 (0.08), and no significant result ($p > 0.05$) for raw data of autumn surveys.

The individuals collected by longline measured 102-156 cm in females and 102-138 cm in males (Fig. 4). They were collected between 200 and 400 m of depth.

Apart from September-October 1997, the sex ratio was significantly in favour of females during each trawl survey ($G = 17.86$; $p < 0.01$). The sex ratio by depth, considered for significant numbers of specimens, was also in favour of females (Fig. 5). The G-test results, obtained with pooled data by season, were highly significant for spring ($G = 87.40$; $p < 0.01$) and significant for autumn ($G = 7.81$; $p < 0.05$).

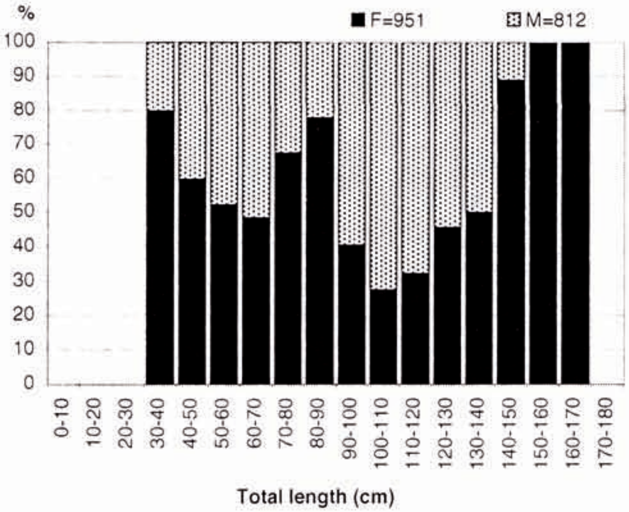

Fig. 6. - Sex ratio by size of *Lepidopus caudatus* sampled in the Ionian Sea during trawl surveys.

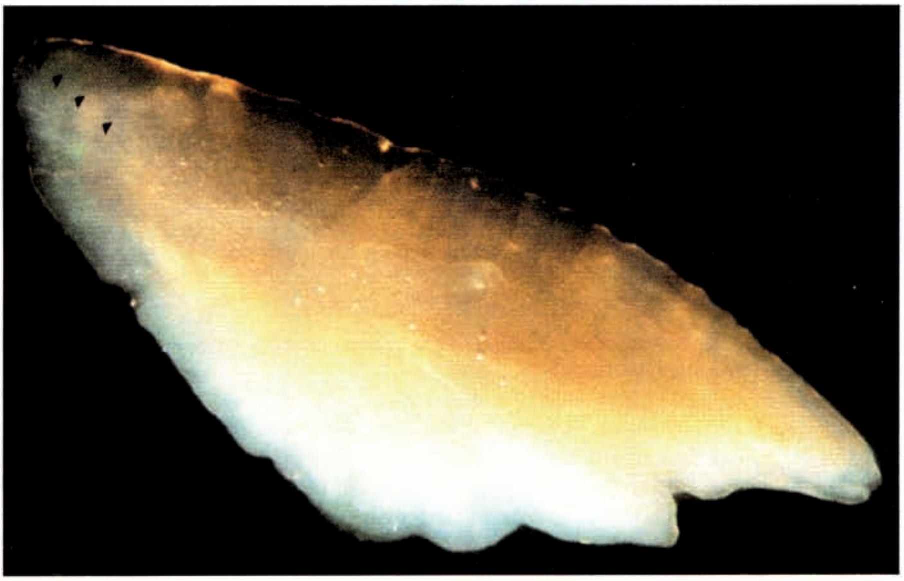

Fig. 7. - Otolith of *Lepidopus caudatus* with indication of the translucent rings (arrowheads).

The sex composition by size changed throughout. It was generally in favour of females within 90 cm, in favour of males between 90 and 130 cm and in favour of females with growing percentages from the latter size to the greatest one (Fig. 6).

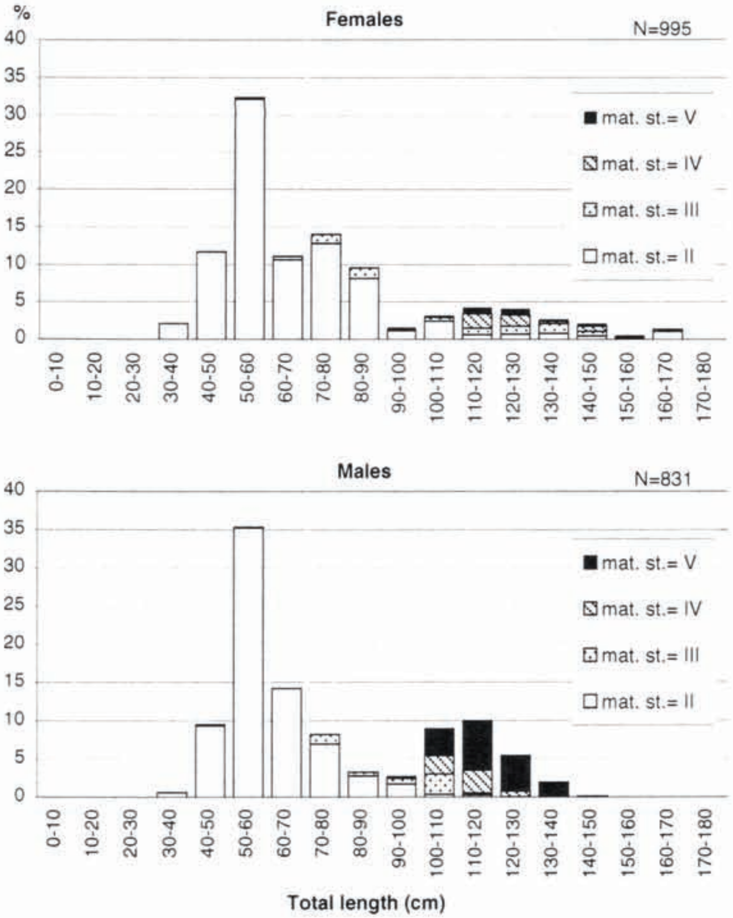

Fig. 8. - Length-frequency distribution by maturity stage of gonads in *Lepidopus caudatus* population sampled in the Ionian Sea during 1996 and 1997.

Age and growth

The otolith of *Lepidopus caudatus* is elongated and the rostrum and antirostrum are clearly differentiated. The otoliths present a large opaque nucleus followed by the annual rings (Fig. 7). The age-length key obtained for each sex is shown in table I. The maximum age was 7+ in females and 5 in males. The von Bertalanffy growth parameters were:

females: $L_\infty = 182.46 \pm 3.9$ cm; $k = 0.30 \pm 0.014$; $t_0 = -0.50 \pm 0.032$; $\phi' = 4.00$
males: $L_\infty = 174.27 \pm 3.7$ cm; $k = 0.31 \pm 0.013$; $t_0 = -0.53 \pm 0.023$; $\phi' = 3.98$

For both sexes the growth rate in the first two years of life appeared to be rather fast, being more than 40 cm of total length per year. Over this period, the growth slowed down mostly in females.

The parameters of the length-weight relationship of both females and males, together with the Chow-test results, are shown in the table II. Apart from autumn 1997, no significant differences were shown between the length-weight relationship of the two sexes.

Table I. - Age-length key of *Lepidopus caudatus* individuals caught in the Ionian Sea.

Total length (cm)	Females															
	Age (year)															
	0	0+	1	1+	2	2+	3	3+	4	4+	5	5+	6	6+	7	7+
160-170															1	1
150-160												3	1			
140-150										7	6	1				
130-140								8	10	3	1					
120-130						1	8	7	1							
110-120						8	3									
100-110					3	6										
90-100				2	15											
80-90				11	2											
70-80			12	6												
60-70			17													
50-60		1	6													
40-50	2	8														
30-40	8	5														
20-30	12															
10-20	1															
N	23	14	35	19	20	15	11	15	11	10	7	4	1	-	1	1
TL mean	29.5	40.8	66.3	82.3	97.5	112.5	121.8	130.3	136.2	142.6	145.1	151.5	153.0	-	163.0	163.5
s.d.	5.7	6.2	6.2	5.5	4.9	6.1	3.2	3.7	3.6	3.0	3.0	2.6	-	-	-	-

Total length (cm)	Males															
	Age (year)															
	0	0+	1	1+	2	2+	3	3+	4	4+	5	5+	6	6+	7	7+
140-150										2	4					
130-140									5	2						
120-130							6	16	1							
110-120						6	17	1								
100-110					7	17	4									
90-100					16											
80-90				13	2											
70-80			12	2												
60-70			18													
50-60		5	3													
40-50		13														
30-40	11															
20-30	12															
10-20	1															
N	24	18	33	14	25	23	27	17	6	4	4					
TL mean	28.9	47.8	67.8	81.3	97.9	106.9	114.8	122.8	132.2	139.8	146					
s.d.	4.5	4.7	5.5	4.4	4.3	3.6	4.1	3.5	3.6	5.1	4.2					

Maturity

The percentage of the maturity stages of both sexes from all samples pooled by season is reported in table III. Immature specimens (stage II) dominated the samples in both spring-summer and autumn. Mature females and males (stage IV) were found in both seasons while running ripe specimens (stage V) were only shown in spring-summer of both years in females and in all surveys in males. No spent individuals were found.

The smallest mature specimen measured 92 cm TL in females and 90 cm in males. Individuals with sizes smaller than these were mostly immature (stage II); above these sizes all maturity stages were almost equally present in females while stages IV and V predominated in males (Fig. 8).

DISCUSSION AND CONCLUSIONS

The *Lepidopus caudatus* population of the Ionian Sea appears to be mostly distributed on the continental shelf and on the epi-bathyal bottoms, as shown in the western Mediterranean (Orsi Relini *et al.*, 1989; Demestre *et al.*, 1993). Although large specimens have been caught in the Ionian Sea between 5 and 8 m of depth with the beach seine in the context of another study (Carbonara *et al.*, 1999), a bigger-shallower trend, as reported by Uiblein *et al.* (1996), has not been revealed by the present data. On the contrary, a broad size range was observed in each bathymetric stratum with the highest density of juveniles on the continental shelf. No convincing results on the relationship between depth and size were provided by the linear regression.

Table II. - Parameters of the length-weight relationship of females and males of *Lepidopus caudatus* caught in the Ionian Sea with the Chow test significance. n.s. = not significant.

	Females				Males				
Survey	**$a*10^{-6}$**	**b**	**r**	**N**	**$a*10^{-6}$**	**b**	**r**	**N**	**Chow test**
Spring 1996	0.228	3.157	0.997	314	0.265	3.131	0.997	207	0.108 (n.s.)
Autumn 1996	0.962	2.931	0.982	131	0.667	2.991	0.987	97	2.520 (n.s.)
Spring 1997	0.330	3.097	0.995	455	0.409	3.065	0.996	444	0.150 (n.s.)
Autumn 1997	0.061	3.355	0.978	51	0.133	3.231	0.994	64	8.665 ($p < 0.05$)

Table III. - Percentage of maturity stage of gonads in *Lepidopus caudatus* population sampled in the Ionian Sea (trawl and longline data).

Maturity	**Spring-Summer 1996**		**Autumn 1996**		**Spring-Summer 1997**		**Autumn 1997**	
stage	**F = 326**	**M = 212**	**F = 131**	**M = 97**	**F = 487**	**M = 458**	**F = 51**	**M = 64**
II	77.3	74.5	86.3	93.8	87.7	62.9	92.3	87.5
III	11.0	9.0	5.3	3.1	6.5	5.0	1.9	3.1
IV	4.0	6.6	8.4	1.0	5.3	7.9	5.8	6.3
V	7.7	9.9	-	2.1	0.4	24.1	-	3.1
VI	-	-	-	-	-	-	-	-
Total	100	100	100	100	100	100	100	100

The three gears used showed different sampling patterns. Commercial trawl net, with a small vertical opening, samples mostly small and immature specimens. Experimental trawl, with a higher vertical opening, catches a significantly greater proportion of adult specimens, although the juveniles still represent the most abundant fraction of the stock. The longline only collects large individuals, according to other observations (Orsi Relini *et al.*, 1989; Demestre *et al.*, 1993; Uiblein *et al.*, 1996).

The more pelagic feeding behaviour of the adults than juveniles (Macpherson, 1979; Palandri and Orsi Relini, 1992; Demestre *et al.*, 1993) together with their faster swimming in the water column make them less vulnerable than juveniles to the trawl. The fact that juvenile individuals experience high levels of mortality by trawling could lead to a "growth overfishing" status of *L. caudatus* stock in the Ionian Sea, even though it is a by-catch species of this fishing technique.

The greater abundance of specimens sampled with the experimental trawl, with a higher vertical opening of the net than the commercial trawl, is surely linked to the pelagic habit of this fish, as observed in the Tyrrhenian Sea (Baino, 1998).

The maximum sizes found during this research were similar for the three gears. Isometric or slightly positive allometric growth was shown between total length and weight in both sexes and seasons. Females seem to grow slightly faster and appear to be more longer-lived than males. The growth of *L. caudatus* in the Ionian Sea showed the same pattern observed in the northwestern Mediterranean (Moli *et al.*, 1990; Demestre *et al.*, 1993), although smaller maximum sizes were found in the former area than in latter. Mikahilin (1976) reported that *L. caudatus* attains 129 cm TL at 9 years in the south-eastern Atlantic and 160 cm TL at 13 years in the north-eastern Atlantic. From the results of the present and other Mediterranean studies (Moli *et al.*, 1990; Demestre *et al.*, 1993), it appears that this fish grows faster in the Mediterranean than in the Atlantic.

The reduction of the growth rate in females was evident between the 2nd and 3rd year according to the beginning of the maturity phase. The slow down in growth was less evident in males due to the fact that males have a lower energetic investment in gonads. It is more costly to produce eggs than sperm, and this is reflected in the growth.

Although it was not possible to define the reproductive peak of *L. caudatus* in the Ionian Sea, data on the maturity stage of the gonads indicate that the reproductive activity of this fish is rather prolonged during the year, as reported by Karlovac and Karlovac (1976), Orsi Relini *et al.* (1989) and Demestre *et al.* (1993). The occurrence of the young-of-the-year both in spring and autumn confirms such prolonged reproduction.

Considering the pelagic behaviour of *L. caudatus* and the different sampling pattern of the gears, this study confirms that reliable estimates of its abundance and the most representative population structure can be only obtained by using as many sampling methods as possible.

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